ORIGINAL ARTICLE

Multidisciplinarity, interdisciplinarity, and transdisciplinarity in health research, services, education and policy: 3. Discipline, inter-discipline distance, and selection of discipline

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Note: Opinions expressed in this paper are solely those of the authors and do not necessarily represent the views of any agencies, organizations or universities.

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Abstract

Background/Purpose. Multiple disciplinary efforts are increasingly encouraged in health research, services, education and policy. This paper is the third in a series. The first discussed the definitions, objectives, and evidence of effectiveness of multiple disciplinary teamwork. The second examined the promoters, barriers, and ways to enhance such teamwork. This paper addresses the questions of discipline, inter-discipline distance, and where to look for multiple disciplinary collaboration.
Methods. This paper proposes a conceptual framework of the knowledge universe, based on a review of a number of key papers on the Global Brain. These key papers were identified during a literature review on multiple disciplinary teamwork, using Google and MEDLINE (1982-2007) searches.
Results. A discipline is held together by a shared epistemology. In general, disciplines that are more disparate from one another epistemologically are more likely to achieve new insight for a complex problem. The proposed conceptual framework of the knowledge universe consists of several knowledge subsystems, each containing a number of disciplines. The inter-discipline distance can guide us to select appropriate disciplines for a multiple disciplinary team.
Conclusion. If multiple disciplinarity is called for, the proposed view of the knowledge universe as a series of knowledge subsystems and disciplines, and the place of health sciences in the knowledge universe, will help researchers, practitioners, and policy makers to identify disciplines for multiple disciplinary efforts.

This is the third in a series of papers focused on a critically important topic of multiple disciplinary efforts in health sciences. The first paper defined differences among multidisciplinary, interdisciplinary and transdisciplinary collaboration, and pointed out that multiple disciplinary teamwork is useful for solving complex real world problems, because such problems do not stay within artificial academic disciplinary boundaries.[1] The second paper provided a practical enumeration of the key ingredients for establishing, promoting, and maintaining collaboration among disciplines, and discussed the promoters, barriers and strategies for teamwork.[2]

This paper, the third in the series, addresses the questions of discipline, inter-discipline distance, and where to look for multiple disciplinary collaboration. It provides a view of the knowledge universe as a framework for seeking and nurturing multiple disciplinary collaboration. It also provides an example of such collaboration, by locating the place of health sciences in the knowledge universe.

In this paper, knowledge refers to the state of knowing; acquaintance with facts, truths, or principles, as from study or investigation.[3] Universe is defined as the totality of known or supposed objects and phenomena throughout space.[3] Epistemology is a branch of philosophy that investigates the origin, nature, methods, and limits of human knowledge.[3] As the terms multidisciplinary, interdisciplinary and transdisciplinary refer to multiple disciplinary to varying degrees on the same continuum,[1] this paper uses the term "multiple disciplinary" to denote all three terms when used in a general sense.

Methods

The conceptual framework of the knowledge universe, proposed in this paper, is based on review of several key documents, including the Global Brain, that were identified in a comprehensive review of the literature based on Google and MEDLINE searches. The literature review methods were described in detail elsewhere.[1,2] Google searches were performed using "multidisciplinarity", "interdisciplinarity", "transdisciplinarity" and "definition" as keywords to identify the pertinent online literature. MEDLINE searches using a similar search strategy were conducted for the period from 1982 to 2007 to identify relevant publications in the medical and scientific literature.

Results

1. Discipline

A discipline is a branch of knowledge, instruction, or learning.[1,3] Examples are biology, history, economics, anthropology, architecture, engineering, and theology.[1] A discipline is held together by a shared epistemology, i.e. assumptions about the nature of knowledge and acceptable ways of generating or accumulating knowledge.[4] For example, the discipline of biology is different from the discipline of history, because of differences in their theories of instruction and learning.

2. Inter-discipline Distance

In epistemology, or the theory of knowledge, some disciplines (e.g. biology and chemistry) are considered closer together, while other disciplines (e.g. biology and history) are deemed farther apart. In the former case, the disciplines of biology and chemistry both employ laboratory techniques. In the latter case, the discipline of biology largely uses quantitative methods, while the discipline of history relies heavily on qualitative methods. In other words, there is a distance between disciplines (epistemological distance). On the basis of epistemological proximity, disciplines often cluster into groups (or knowledge subsystems) such as: the natural sciences (e.g. physics, chemistry, biology), the social sciences (e.g. psychology, sociology, economics), the humanities (e.g. languages, music, visual arts), among others. Disciplines that belong to the same knowledge subsystems are closer together, but those that belong to different subsystems are farther away from each other.

Professional programs (e.g. Medicine, Dentistry, Nursing, Public Health, Law, Education) generally operate on a multidisciplinary model, drawing on ways of knowing from the sciences, social sciences, humanities, and others.[4] Thus, professional programs are more than disciplines, and in some cases may bridge across knowledge subsystems.

In general, multiple disciplinary thinking that combines disciplines that are more disparate or different from one another epistemologically (e.g. biology and history) is more likely to achieve new insight for a complex problem or issue than disciplines that share similar epistemological assumptions (e.g. biology and chemistry). Several examples are provided in our previous paper.[1] A painting by Giotto can be studied by the discipline of visual arts, but may be more fruitful if it can also be studied from the perspectives of European history, and geometry.[1] Combining nuclear physics with medicine leads to new treatments for cancer, and transferring computer technology to art leads to computer art.[1] Different disciplines provide different methods and perspectives, making it possible to see different facets of a crystal by rotating it.[1] By having more disciplines that are more distant from each other, it is more likely to be successful in recombining information elements that are present in a complex question, leading to the cognitive process of emergence of new ideas and knowledge, and hence the solution to the question.[1] Multiple disciplines can give that complex question at hand a "look in" from many different perspectives.[1] The more disparate the disciplines, the more different the perspectives, which leads to a greater chance of success in tackling a complex problem.

3. Where to Look for Multiple Disciplinary Collaboration

In writing about the global village in 1962, McLuhan described how electronic mass media collapse space and time barriers in human communication, enabling people to interact and live on a global scale.[5] In this sense, the globe has been turned into a village by the electronic mass media. Russell, in 1983, described a Global Brain that might emerge from a worldwide network of humans linked through modern communication technology, such as computers, satellites, fibre optics and video recorders.[6] Human minds on the globe become analogous to nerve cells in a brain, with the communication system serving as the nervous system.[7] This is a useful conceptual model for multiple disciplinary teamwork. In describing the design criteria for a Global Brain, Turnbull in 2001 suggests a hierarchy of connecting disciplines in nature (Table 1).[8] Each discipline is divided into three arbitrary "levels" of first, second and third. The third level of a discipline becomes the first level of the discipline in the next tier.

TABLE 1. Hierarchy of disciplines in natural sciences (Source: adapted from Turnbull, 2001)[8]

Discipline	First level	Second level	Third level
1. Physics	Particles	Atoms	Molecules
2. Chemistry	Molecules	Compounds	Bases
3. Genetics	Bases	DNA*	Genes
4. Biology	Genes	Chromosomes	Cells
5. Anatomy	Cells	Organs	Individuals (Biota#)
6. Geography	Biota	Ecological systems	Gaia@ (Earth)
7. Astronomy	Earth	Solar system	Galaxy

* DNA, deoxyribonucleic acid.
# Biota, the combined fauna (animals) and flora (plants) of a geographical area.
@ Gaia, the goddess of earth.

In a way similar to what Turnbull proposes, we propose that other knowledge subsystems be created. These include the hierarchies of disciplines in health sciences (Table 2), social sciences (Table 3), engineering sciences (Table 4), management (Table 5) and humanities (Table 6). For illustrative purposes, each knowledge subsystem has 7 arbitrary tiers of disciplines; each discipline has 3 arbitrary levels.

Our view of the knowledge universe, with six arbitrary subsystems (Tables 1-6), each subsystem with 7 arbitrary disciplines, and each discipline with 3 arbitrary levels, was developed as follows. First, the knowledge universe, being the totality of known and supposed state of knowing and acquaintance with facts, truths and principles, was presumed to mirror

TABLE 2. Hierarchy of disciplines in health sciences

Discipline	First level	Second level	Third level
1. Pharmacology	Active sites	Radicals	Biomolecules
2. Biochemistry	Biomolecules	DNA	Cells
3. Physiology	Cells	Vital processes	Body functions
4. Pathology	Body functions	Body structures	Health
5. Epidemiology	Health	Health risks	Disease
6. Clinical medicine	Disease	Therapy	Disability
7. Palliative medicine	Disability	Rehabilitation	Death

TABLE 3. Hierarchy of disciplines in social sciences

Discipline	First level	Second level	Third level
1. Clinical psychology	Nerves	Brain	Consciousness
2. Psychology	Consciousness	Behavior	Individuals
3. Sociology	Individuals	Groups	Communities
4. Economics	Communities	Firms	Institutions
5. Political sciences	Institutions	Governments	Nations
6. International studies	Nations	Alliances	World
7. Theology	World (Material world)	Spiritual world	Divinity

TABLE 4. Hierarchy of disciplines in engineering sciences

Discipline	First level	Second level	Third level
1. Mathematics	Logical reasoning	Numbers	Quantity
2. Electrical engineering	Quantity	Charges	Electricity
3. Computer engineering	Electricity	Circuits	Devices
4. Mechanical engineering	Devices	Machines	Structures
5. Civil engineering	Structures	Bridges	Buildings
6. Urban planning	Buildings	Neighborhoods	Cities
7. Space engineering	Cities	Space	Outer space

TABLE 5. Hierarchy of disciplines in management

Discipline	First level	Second level	Third level
1. Accounting	Numbers	Auditing	Financial statements
2. Finance	Financial statements	Investment	Money markets
3. Marketing	Money markets	Promotions	Markets
4. Human resource management	Markets	Labour relations	Human resources
5. Business administration	Human resources	Companies	Businesses
6. Commerce	Businesses	Trade	Import and export
7. International management	Import and export	International businesses	Global economy

TABLE 6. Hierarchy of disciplines in humanities

Discipline	First level	Second level	Third level
1. History	Evidence	Records	Events
2. Languages	Events	Expressions	Sounds
3. Music	Sounds	Rhythms	Patterns
4. Visual arts	Patterns	Perceptions	Images
5. Theatre	Images	Multi-media	Ideas
6. Communication	Ideas	Transmission	Information
7. Philosophy	Information	Knowledge	Wisdom

the curriculum (course) structure of the university, the institution of learning of the highest level. A university normally comprises several schools of learning (faculties), each with several departments of learning (departments). The faculties correspond roughly to the knowledge subsystems (a group of related branches of learning), and the departments correspond roughly to the disciplines (a branch of learning).

Second, we then examined the prospectuses and handbooks of a large number of universities worldwide. A typical university has the following faculties (each with its approximate corresponding knowledge subsystem): Faculty of Science (subsystem of natural sciences); Faculty of Medicine (subsystem of health sciences); Faculty of Social Science (subsystem of social sciences); Faculty of Engineering (subsystem of engineering sciences); Faculty of Management (subsystem of management); Faculty of Arts (subsystem of humanities). There are other smaller faculties (such as Dentistry, Nursing, Pharmacy, Law, Architecture, Education, Forestry, Social Work, Music, and others) which, for the sake of clarity and brevity, were excluded from or considered to be part of the six chosen subsystems. For example, Dentistry, Nursing and Pharmacy are very close to Medicine and all are considered to be mainly related to the subsystem of health sciences. Music is considered part of the subsystem of humanities.

Third, we examined the list of academic departments in each university faculty, and selected an arbitrary number of seven departments to represent the range of disciplines from microcosmic (the little world) to macrocosmic (the great world). We also consulted dictionary and textbook definitions of the discipline to help us select the three levels within a discipline. Using Table 1 as an example: physics is defined in the dictionary as "the science that deals with matter, energy, motion, and force".[3] An encyclopedia, in part, describes physics (especially atomic and nuclear physics) as the study of elementary particles, and states that "physics is closely allied to other sciences, particularly chemistry in atomic research and development".[9] Thus the 3 levels chosen for physics were particles, atoms, and molecules (Table 1). At the level of molecules, physics enters into chemistry, the next tier of discipline in the natural sciences subsystem (Table 1). In a similar way, chemical compounds, genetic materials, body cells, and individuals represent increasingly larger scales of the science or study. Finally, while the discipline of geography, the science dealing with the areal differentiation of the earth's surface,[3] goes from biota (vegetation and population) to the earth (the planet we live on), the discipline of astronomy, the science that deals with the material universe beyond the earth's atmosphere,[3] carries the knowledge further from the earth to the galaxy (Table 1). Thus, disciplines in the natural sciences subsystem cover a wide range from the particle level (microcosmic) to the galaxy level (macrocosmic).

Fourth, to be consistent we set up all six knowledge subsystems in the same arbitrary format of 7 disciplines and 3 levels, covering sciences from microcosmic to macrocosmic (Tables 1-6). We will use epidemiology and psychology as two examples, because of our particular expertise and our doctoral training in epidemiology (BC) and psychology (AP). Epidemiology, the study of the distribution and determinants of health-related states or events in specified populations and the application of this study to control of health problems,[10] covers the three levels from the state of health, through exposure to health risks such as a virus or physical inactivity, to the state of ill-health (disease), at the population level (Table 2). Epidemiology takes over from pathology, the study of the origin, nature, and course of disease,[3] because pathology looks at the change from the state of health to the state of ill-health at the individual level, and epidemiology expands the science of pathology to the population level. Epidemiology in turn passes science onto medicine, the science of treating disease,[3] which when it fails results in disability or death (arguably the worst levels in health) at the individual or population level (Table 2).

Psychology is defined as the science of mental life, both of its phenomena and of their condition,[11] namely, the science of human behaviour.[3] In a university, psychology is often grouped under the Faculty of Arts and Science, which is an umbrella for life sciences, physical sciences, mathematical sciences, computer sciences, social sciences, humanities, and commerce (for example, see University of Toronto prospectus). It belongs to the subsystem of social sciences, because it deals with the consciousness and psychosocial behaviour of individuals (Table 3). Psychology takes over from clinical psychology (which in many universities would be grouped under the Faculty of Medicine because of its clinical nature, but in our opinion it provides the subcellular basis for psychosocial phenomena and therefore, at least in part, the foundation for social sciences). From psychology the work goes on to sociology, the science of the origin, development, organization, and functioning of human society.[3] Psychology deals with psychosocial phenomena at the individual level, and sociology deals with these phenomena at the society level.

Our proposed segregation of the knowledge universe into knowledge subsystems, as shown in Tables 1 to 6, helps us to know where to look for different disciplines for a teamwork to solve a real world complex problem. If the problem is not very complex, disciplines from the same knowledge subsystem may suffice, for example, health sciences (Table 2). But, if the problem to be solved is more complex, then disciplines from two or more knowledge subsystems may be required, for example, health sciences (Table 2), social sciences (Table 3) and management (Table 5). Also, the knowledge universe and its subsystems, as presented in this paper, can serve as a checklist for us to think through carefully whether there are other relevant but overlooked disciplines to be considered. This allows us to ensure comprehensiveness in the selection of disciplines for a multiple disciplinary team.

4. An Example: The Place of Health Sciences in the Knowledge Universe

In order to adopt a multiple disciplinary approach to tackle problems in health research, services, education and policy, it is important to understand the place of health sciences in the knowledge universe. Health sciences is a knowledge subsystem, situated among many other knowledge subsystems in the knowledge universe. Health sciences is so close epistemologically to some other knowledge subsystems, that it can easily interact with or enter into another through closely related disciplines. For example, health sciences (Table 2), through biochemistry or physiology, can enter into natural sciences (Table 1) through biology or anatomy, at the level of cells. Other knowledge subsystems are more disparate.

It is not impossible for distant knowledge subsystems to interact with each other. There are already successful examples of multiple disciplinary interactions of health sciences with other knowledge subsystems close or distant e.g. the discipline of epidemiology (Table 2). Multiple disciplinary efforts are now established across disciplines within health sciences, such as pharmaco-epidemiology (with pharmacology),[12] molecular epidemiology (with biochemistry),[13] nutritional epidemiology (with physiology), [14] and clinical epidemiology (with clinical medicine),[15] Similar efforts are also established across knowledge subsystems, such as genetic epidemiology (with genetics),[16] geographical epidemiology (with geography),[17] psychoepidemiology (with psychology),[18] social epidemiology (with sociology),[19] theoretical epidemiology (with mathematics),[20] historical epidemiology (with history),[21] and translational epidemiology (with communication),[22] As shown in Tables 1-6, however, there is still room for epidemiology to team up with many other disciplines.

Discussion

Following the initial work of McLuhan,[5] Russell,[6,7] and Turnbull,[8] this paper proposes a view of the knowledge universe, a framework of knowledge subsystems, and the place of health sciences in the knowledge universe, as a way to look for and nurture multiple disciplinary efforts. The proposed view of the knowledge universe emphasizes the connectivity of disciplines, and allows researchers, practitioners and policy makers to choose disciplines for a multiple disciplinary team to tackle complex real world problems.

On first reading, this paper might look like a complex menu in a restaurant in a foreign country. This is partly true given that any real world complex problem would be foreign to any single discipline, and hence would require a multiple disciplinary approach.[1] For example, if you are a natural scientist (e.g. a physicist), you would be familiar with Table 1, but other tables such as Table 5 for management experts (familiar to an accountant) or Table 6 for humanity experts (familiar to a historian) would be foreign to you. There are a few techniques to order from a foreign menu (to use Tables 1-6 in this paper). First, you need to ask what you want to eat. If you have in mind specific choices like seafood or vegetarian (simple problems), you can simply pick a few dishes (closely related disciplines) from a certain food category (knowledge subsystem). But if you're not sure what you want, or if you want to taste a bit of everything (complex problems), you can pick from different food categories on the menu. The more the food categories (knowledge subsystems), the more likely you will get the dish you want (the solution to the question). However, it may not always be prudent, or necessary, to order from all over the menu, for that may lead to surplus food (unused expertise), heart-burn (discipline conflicts),[2] and an expensive dinner bill (wasteful resources).

Our proposed view of the knowledge universe has several characteristics. First, the knowledge universe is a system of many knowledge subsystems, namely natural sciences, health sciences, social sciences, engineering sciences, management and humanities. Second, each subsystem consists of a number of connecting disciplines each having several levels, allowing knowledge to be passed from one level to another, and from one discipline to another. Third, the subsystems closely mirror each other at various tiers, from microcosmic to macrocosmic, allowing knowledge to be passed from one subsystem to another.

The proposed view, however, is not intended to be a rigid framework for debating on the exact place or content of a discipline. Rather, it serves to allow us to more fully appreciate the intricate linkage of disciplines, their epistemological distances from each other, the vastness of the knowledge universe, and to identify where to foster potential multiple disciplinary efforts.

Once the types of disciplines are chosen from the knowledge universe for a multiple disciplinary team using methods described in this paper, readers are then referred back to our first paper to identify the best type of involvement of multiple disciplines (i.e. multi-, inter-, or trans-),[1] and to our second paper to apply the eight strategies to ensure success of multiple disciplinary teamwork (as summarised in the eight letters of the acronym TEAMWORK - Team, Enthusiasm, Accessibility, Motivation, Workplace, Objectives, Role, Kinship).[2]

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